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(71)出願人　000002004
昭和電工株式会社
東京都港区芝大門１丁目13番９号

(72)発明者　山下　任
千葉県千葉市緑区大野台１－１－１　昭和電工株式会社総合研究所内

(72)発明者　宇田川　隆
埼玉県秩父市大字下影森1505番地　昭和電工株式会社総合研究所秩父研究室内

(74)代理人　100118740
弁理士　柿沼　伸司

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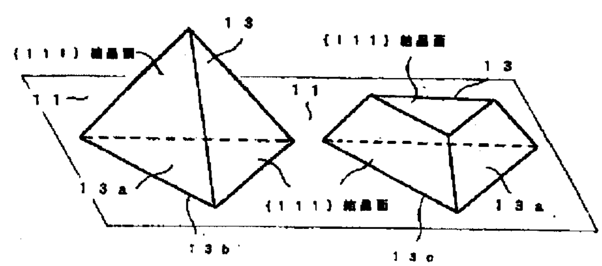
(54)【発明の名称】　リン化硼素系半導体素子、その製造方法、発光ダイオードおよびリン化硼素系半導体層

(57)【要約】
【課題】本発明は、特定の結晶方向を双晶面とする双晶を安定して含む多結晶のリン化硼素系半導体層を備えることにより、特性の向上したリン化硼素系半導体素子を提供する。
【解決手段】基板を、表面を｛１１１｝結晶面とする｛１１１｝－Ｓｉ単結晶とし、その上に積層するリン化硼素系半導体層を、｛１１１｝結晶面からなる底面を有し、且つ｛１１１｝結晶面と等価な面で囲まれた、複数の四角錘状のリン化硼素系半導体結晶の単結晶体を集合させた多結晶層から構成するものとし、さらに単結晶体は基板の＜１１０＞結晶方向に対して６０度の角度で傾いた双晶境界面を有するものとする。



【特許請求の範囲】

【請求項１】珪素（Ｓｉ）単結晶からなる基板と、該基板の表面上に形成された、基板の表面を構成する結晶面と同一の結晶面を有するリン化硼素系半導体結晶からなるリン化硼素系半導体層とを備えたリン化硼素系半導体素子に於いて、前記の基板が、表面を｛１１１｝結晶面とする｛１１１｝－Ｓｉ単結晶からなり、前記のリン化硼素系半導体層は、基板の｛１１１｝結晶面に平行に配列したリン化硼素系半導体結晶の｛１１１｝結晶面からなる底面を有し、且つ｛１１１｝結晶面と等価な面で囲まれた、複数の四角錘状のリン化硼素系半導体結晶の単結晶体を集合させた多結晶層から構成され、さらに該単結晶体が、基板の<１１０>結晶方向に対して６０度の角度で傾いた双晶境界面を有することを特徴とするリン化硼素系半導体素子。

【請求項２】前記リン化硼素系半導体層の上にＩＩＩ－Ｖ族化合物半導体層が積層されて形成された異種（ヘテロ）接合を有し、該ＩＩＩ－Ｖ族化合物半導体層が、リン化硼素系半導体層をなす単結晶体の表面に交差する結晶面の面間隔（格子間隔）に一致する間隔で配列した結晶面から構成されることを特徴とする請求項１に記載のリン化硼素系半導体素子。

【請求項３】前記リン化硼素系半導体結晶の単結晶体が、単量体のリン化硼素（ｂｏｒｏｎ　ｍｏｎｏｐｈｏｓｐｈｉｄｅ）結晶からなることを特徴とする請求項１または２に記載のリン化硼素系半導体素子。

【請求項４】前記リン化硼素系半導体層を、｛１１１｝－Ｓｉ単結晶基板上に９５０℃以上１１００℃以下の温度に於いて、有機金属熱分解気相成長法（ＭＯＣＶＤ法）により、成長速度を毎分２０ｎｍ以上６０ｎｍ以下として形成することを特徴とする請求項１ないし３に記載のリン化硼素系半導体素子の製造方法。

【請求項５】前記リン化硼素系半導体層を、｛１１１｝－Ｓｉ単結晶基板上に１０２５℃以上１０７５℃以下の温度に於いて、有機金属熱分解気相成長法（ＭＯＣＶＤ法）により、成長速度を毎分３０ｎｍ以上４０ｎｍ以下として形成することを特徴とする請求項４に記載のリン化硼素系半導体素子の製造方法。

【請求項６】請求項１ないし３に記載のリン化硼素系半導体素子からなる発光ダイオード。

【請求項７】珪素（Ｓｉ）単結晶からなる基板の表面上に形成された、基板の表面を構成する結晶面と同一の結晶面を有するリン化硼素系半導体結晶からなるリン化硼素系半導体層に於いて、前記の基板が、表面を｛１１１｝結晶面とする｛１１１｝－Ｓｉ単結晶からなり、前記のリン化硼素系半導体層は、基板の｛１１１｝結晶面に平行に配列したリン化硼素系半導体結晶の｛１１１｝結晶面からなる底面を有し、且つ｛１１１｝結晶面と等価な面で囲まれた、複数の四角錘状のリン化硼素系半導体結晶の単結晶体を集合させた多結晶層から構成され、さらに該単結晶体が、基板の<１１０>結晶方向に対して６０度の角度で傾いた双晶境界面を有することを特徴とするリン化硼素系半導体層。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、珪素（Ｓｉ）単結晶（シリコン）基板上に形成した、リン化硼素系半導体素子を得るに好適となるリン化硼素系半導体層の結晶構成と、それを具備したリン化硼素系半導体素子に関する。

【０００２】

【従来の技術】従来にあって、硼素（Ｂ）とリン（Ｐ）とを構成元素として含むリン化硼素系半導体の一種であるリン化硼素（ＢＰ）を利用して発光ダイオード（ＬＥＤ）或いはレーザダイオード（ＬＤ）等の半導体発光素子を形成する技術が知れている（米国特許第６、０６９、０２１号参照）。従来のリン化硼素系半導体発光素子は、例えば、珪素単結晶（シリコン）からなる基板上に形成されたリン化硼素層を緩衝層として含む積層構造体を用いて構成されている（上記の米国特許第６、０６９、０２１号参照）。最近では、ワイドバンドギャップのリン化硼素層を障壁（クラッド）層とするｐｎ接合型二重ヘテロ構造を発光部を備えた半導体発光素子用途の積層構造体も発明されている（特願２００１－１５８２８２号参照）。

【０００３】従来より、シリコン基板上には、基板表面をなす結晶面と同一の結晶面からなるリン化硼素の単結晶層が成長することが判明している。例えば表面を｛１００｝結晶面とする｛１００｝－Ｓｉ単結晶基板上には、基板表面に平行に積重した｛１００｝結晶面からなるリン化硼素単結晶層が成長するのが知れている（庄野克房著、「半導体技術（上）」（１９９２年6月２５日、（財）東京大学出版会発行第９刷、７７頁参照）。また、シリコン基板上には、双晶（ｔｗｉｎｎｉｎｇ）を全く含まないリン化硼素単結晶層が成長できることも知れている（上記の「半導体技術（上）」、９８頁参照）。一方では双晶を含む｛１００｝-リン化硼素単結晶層も得られるのが知れている（上記の「半導体技術（上）」、９９～１００頁参照）。

【０００４】

【発明が解決しようとする課題】従来技術が開示するところでは、リン化硼素層に含まれる双晶は、結晶格子間の不整合率を緩和する様な特徴をもっているとされる（上記の「半導体技術（上）」、１００頁参照）。従って、双晶を含むリン化硼素系半導体層を利用すれば特性、例えば、発光強度に優れるＬＥＤを得るに貢献できる。しかし、従来技術が開示する如く、双晶を含むリン化硼素系半導体層を安定して得るのは困難となっている。即ち、従来は双晶を安定して含むリン化硼素系半導体層を製造するための要件が明かとなってはいないた

め、例えば、発光の強度に優れる発光素子を安定して獲得するに支障を来している。

【０００５】本発明は、双晶を安定して含ませることができる結晶構成からなるリン化硼素系半導体層を提供することを目的とする。また、本発明では、特定の結晶方向を双晶面とする双晶を安定して含む多結晶のリン化硼素系半導体層を備えることにより、特性の向上したリン化硼素系半導体素子を提供する。ここで本発明の目的とする結晶構造からなるリン化硼素系半導体層とは、従来の膜状の単結晶からなるのではなく、双晶境界面（双晶面）（Ｃ．Ｗ．バン著、「化学結晶学」（昭和４５年６月１５日、（株）培風館発行初版、７５～７６頁参照）の結晶方向を相違する単結晶体を集合させてなる多結晶からなるリン化硼素系半導体層である。

【０００６】

【課題を解決するための手段】即ち、本発明は、（１）珪素（Ｓｉ）単結晶からなる基板と、該基板の表面上に形成された、基板の表面を構成する結晶面と同一の結晶面を有するリン化硼素系半導体結晶からなるリン化硼素系半導体層とを備えたリン化硼素系半導体素子に於いて、前記の基板が、表面を｛１１１｝結晶面とする｛１１１｝－Ｓｉ単結晶からなり、前記のリン化硼素系半導体層は、基板の｛１１１｝結晶面に平行に配列したリン化硼素系半導体結晶の｛１１１｝結晶面からなる底面を有し、且つ｛１１１｝結晶面と等価な面で囲まれた、複数の四角錘状のリン化硼素系半導体結晶の単結晶体を集合させた多結晶層から構成され、さらに該単結晶体が、基板の<１１０>結晶方向に対して６０度の角度で傾いた双晶境界面を有することを特徴とするリン化硼素系半導体素子。である。

【０００７】また本発明は、（２）前記リン化硼素系半導体層の上にＩＩＩ－Ｖ族化合物半導体層が積層されて形成された異種（ヘテロ）接合を有し、該ＩＩＩ－Ｖ族化合物半導体層が、リン化硼素系半導体層をなす単結晶体の表面に交差する結晶面の面間隔（格子間隔）に一致する間隔で配列した結晶面から構成されることを特徴とする上記（１）に記載のリン化硼素系半導体素子。

（３）前記リン化硼素系半導体結晶の単結晶体が、単量体のリン化硼素（ｂｏｒｏｎ　ｍｏｎｏｐｈｏｓｐｈｉｄｅ）結晶からなることを特徴とする上記（１）または（２）に記載のリン化硼素系半導体素子。

【０００８】また本発明は、（４）前記リン化硼素系半導体層を、｛１１１｝－Ｓｉ単結晶基板上に９５０℃以上１１００℃以下の温度に於いて、有機金属熱分解気相成長法（ＭＯＣＶＤ法）により、成長速度を毎分２０ｎｍ以上６０ｎｍ以下として形成することを特徴とする上記（１）ないし（３）に記載のリン化硼素系半導体素子の製造方法。（５）前記リン化硼素系半導体層を、｛１１１｝－Ｓｉ単結晶基板上に１０２５℃以上１０７５℃以下の温度に於いて、有機金属熱分解気相成長法（ＭＯＣＶＤ法）により、成長速度を毎分３０ｎｍ以上４０ｎｍ以下として形成することを特徴とする上記（４）に記載のリン化硼素系半導体素子の製造方法。である。

【０００９】また本発明は、（６）上記（１）ないし（３）に記載のリン化硼素系半導体素子からなる発光ダイオード。である。

【００１０】また本発明は、（７）珪素（Ｓｉ）単結晶からなる基板の表面上に形成された、基板の表面を構成する結晶面と同一の結晶面を有するリン化硼素系半導体結晶からなるリン化硼素系半導体層に於いて、前記の基板が、表面を｛１１１｝結晶面とする｛１１１｝－Ｓｉ単結晶からなり、前記のリン化硼素系半導体層は、基板の｛１１１｝結晶面に平行に配列したリン化硼素系半導体結晶の｛１１１｝結晶面からなる底面を有し、且つ｛１１１｝結晶面と等価な面で囲まれた、複数の四角錘状のリン化硼素系半導体結晶の単結晶体を集合させた多結晶層から構成され、さらに該単結晶体が、基板の<１１０>結晶方向に対して６０度の角度で傾いた双晶境界面を有することを特徴とするリン化硼素系半導体層。である。

【００１１】

【発明の実施の形態】本発明では、リン化硼素系半導体層は｛１１１｝結晶面を表面とするＳｉ単結晶基板（本明細書では、｛１１１｝－Ｓｉ単結晶基板と記載する。）上に好適に形成できる。ダイヤモンド（ｄｉａｍｏｎｄ）結晶構造型のＳｉ単結晶の｛１１１｝結晶面には、｛１００｝或いは｛１１０｝結晶面よりも密に珪素原子が存在している。従って、｛１１１｝－Ｓｉ単結晶基板では、その上に堆積するリン化硼素系半導体層の構成元素の基板内部への拡散、浸透を抑制できる利点があり、明瞭な接合界面を構成するに効果を奏する。導電性を有する｛１１１｝－Ｓｉ単結晶基板ではまた、裏面に正負、何れかの極性のオーミック（Ｏｈｍｉｃ）性電極を裏面電極して敷設でき、例えば、発光素子を簡便に構成するに効果を上げられる。特に、抵抗率を１ミリオーム（ｍΩ）以下、より望ましくは０．１ｍΩ以下とする低い比抵抗（抵抗率）の導電性単結晶基板は、順方向電圧（所謂、Ｖｆ）の低いＬＥＤをもたらすに貢献する。また、放熱性に優れるため安定した発振をもたらすＬＤを構成するに有効となる。

【００１２】好ましくは｛１１１｝－Ｓｉ基板表面上に積層する多結晶層のリン化硼素系半導体層は、硼素（Ｂ）とリン（Ｐ）とを構成元素として含む例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}As_{\delta}$層（$0<\alpha\leqq1$、$0\leqq\beta<1$、$0\leqq\gamma<1$、$0<\alpha+\beta+\gamma\leqq1$、$0\leqq\delta<1$）とする。また、例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}N_{\delta}$（$0<\alpha\leqq1$、$0\leqq\beta<1$、$0\leqq\gamma<1$、$0<\alpha+\beta+\gamma\leqq1$、$0\leqq\delta<1$）から構成する。単量体のリン化硼素（ｂｏｒｏｎ　ｍｏｎｏｐｈｏｓｐｈｉｄｅ：ＢＰ）は、構成元素が硼素（Ｂ）と

リン（Ｐ）のみであり、多元混晶よりも構成元素が少なく成膜が容易であるという利点があるため特に好ましい。また、例えば、有機金属熱分解気相成長（ＭＯＣＶＤ）手段に依り、成長速度を毎分２ｎｍ以上で３０ｎｍ以下とし、リン等のＶ族元素と硼素等のＩＩＩ族元素の原料の供給比率（所謂、Ｖ／ＩＩＩ比）を１５以上で６０以下の範囲として成長したリン化硼素は、室温での禁止帯幅を約３ｅＶとするワイドバンドギャップ（ｗｉｄｅ　ｂａｎｄｇａｐ）半導体となる。この様な禁止帯幅の広いリン化硼素半導体層は例えば、発光素子にあって、発光層に対する障壁（ｃｌａｄ）層として利用できる。

【００１３】多結晶層のリン化硼素系半導体層は、本発明では、複数のリン化硼素系半導体結晶からなる単結晶体を集合させて構成する。本発明に係わる多結晶層を構成する単結晶体の形状を図１に模式的に示す。｛１１１｝－Ｓｉ単結晶基板１１上の各単結晶体１３は、周囲をリン化硼素系半導体結晶の｛１１１｝結晶面と等価な面とする正四角錘体１３ｂ或いは正四角錘体の頂部を｛１１１｝結晶面とする四角錐状体１３ｃの外形をなしている。各単結晶体１３の底面１３ａは、｛１１１｝－Ｓｉ単結晶基板の｛１１１｝結晶面に平行に配置されたリン化硼素系半導体結晶の｛１１１｝結晶面からなる。底面１３ａとは、｛１１１｝－Ｓｉ単結晶基板１１の表面に接地している結晶面である。

【００１４】本発明の多結晶層は、図２の平面模式図に示す如く、上記の複数の四角錐状の単結晶体１３を相互に結合させて構成されている。各単結晶体１３は接合面１６を介して互いに連結している。各単結晶体１３の内部には、双晶１５を存在させてある。各単結晶体１３の内部に含ませた双晶面１４の存在する方向が画一的に一定ではないため、その様な異なる結晶方向に双晶を含む各々の単結晶体１３から構成されているリン化硼素系半導体層を、本発明では多結晶層と称している。本発明では特に、基板をなす｛１１１｝－Ｓｉ単結晶の<１１０>結晶方向に対し角度にして６０度（°）の方向に双晶面を規則的に含ませた単結晶体１３を集合させて多結晶層を構成する。ここで云う双晶面とは、具体的には、リン化硼素系半導体結晶の｛１１１｝結晶面に等価な面である。即ち、｛１１１｝、｛－１．－１．－１．｝、｛１．－１．１．｝等の結晶面である。また、双晶面は、四角錐状の単結晶体１３の周囲を構成するリン化硼素系半導体結晶の何れかの｛１１１｝結晶面に平行となっているのが特徴である。リン化硼素系半導体結晶の｛１１１｝結晶面を双晶面１４とする双晶１５の発生に因り、Ｓｉ単結晶基板とリン化硼素系半導体結晶との格子ミスマッチに起因するミスミット（ｍｉｓｆｉｔ）転位の発生、伝搬を効果的に抑制できる。リン化硼素系半導体結晶では、｛１１１｝結晶面を双晶面とする双晶は、他の結晶面を双晶面とする双晶に比較して安定して且つ容易に形成することができる。従って、リン化硼素系半導体結晶の｛１１１｝結晶面を双晶面とする双晶を含む単結晶体を集合させて多結晶層を構成すれば、ミスフィット転位の伝搬を安定して抑制するに効力を発揮できる。

【００１５】双晶の存在は例えば、電子線回折技法により撮像された電子線回折図形（パターン）上の異常回折斑点（ｓｐｏｔ）の有無より知れる（坂　公恭著、「結晶電子顕微鏡学」、１９９７年１１月２５日、（株）内田老鶴圃発行第１版、１１１～１１３頁参照）。また、入射電子線をリン化硼素系半導体層の<１１０>結晶方向に平行として撮像した回折図形上の<１１０>結晶方向と双晶に起因する回折斑点とのなす角度を計測すれば、<１１０>結晶方向と双晶とがなす角度を知ることができる。因みに、双晶はまた、一種の積層欠陥（ｓｔａｃｋｉｎｇ　ｆａｕｌｔ）と見なすこともできる（上記の「結晶電子顕微鏡学」、１１２頁参照）。

【００１６】本発明に係わる双晶を含む単結晶体を集合させた多結晶層を得るには、成膜時の条件を精密に制御する必要がある。特に、｛１１１｝結晶面を双晶面とする双晶を含むリン化硼素系半導体結晶からなる四角錘状の単結晶体は、例えば、トリエチル硼素（$(C_2H_5)_3B$）／ホスフィン（PH_3）／水素（H_2）を原料系とする常圧の有機金属熱分解気相成長法（ＭＯＣＶＤ法）によって、成長温度を精密に制御して形成する。上記ＭＯＣＶＤ手段にあって、リン化硼素系半導体多結晶層、特に、単量体のリン化硼素の多結晶層を得るに好適な温度の範囲は、９５０℃以上１１００℃以下さらに好ましくは１０２５℃～１０７５℃の範囲である。インジウム（Ｉｎ）を含むリン化硼素系半導体多結晶層の形成には、より低温の約９５０℃～約１０００℃が好適である。アルミニウム（Ａｌ）を構成元素として含むリン化硼素系半導体多結晶層は、比較的に高温の約１０５０℃～１１００℃が好適である。約１２００℃を越える高温では、BP_6、$B_{13}P_2$等のリン化硼素多量体が発生し易くなり、組成的に均質なリン化硼素系半導体層を得るに不都合となる。

【００１７】また、双晶を内在する単結晶体を効率的に形成するには、成長の速度を毎分２０ｎｍから毎分６０ｎｍの範囲とするのが望ましい。単量体のリン化硼素（ＢＰ）にあっては、毎分３０ｎｍ～４０ｎｍの成長の速度が特に好適である。６０ｎｍを越える速度で成長させた単結晶体には、多量の双晶（積層欠陥）に加え、点欠陥や転位等の他の結晶欠陥の密度が急激に増加する不都合を生じ、結晶性に優れる多結晶層を得るに困難を来す。逆に、成長速度を小さくすると、即ち、所望の層厚のリン化硼素系半導体層を得るにより長時間を要する状況とすると、成長時に於いて構成元素のリン（Ｐ）の揮散する機会が増す。このため、２０ｎｍ／分未満の小さな成長速度は、リン（Ｐ）の蒸発、揮散に起因するリン

化硼素系半導体層の構成元素間での化学的な当量比の不均衡が急激に発生する。化学量論的に不均衡な組成のリン化硼素系化合物半導体層には、点欠陥が多量に含まれているため本発明に係わる多結晶層とするには不適である。

【００１８】単結晶体の内部に含まれる双晶は、例えば、基板のＳｉ単結晶と単結晶体を構成するリン化硼素系半導体との格子ミスマッチに起因して発生するミスフィット転位の伝搬を抑制する作用を有する。例えば、Ｓｉ基板と単結晶体との接合界面から発生したミスフィット転位は、単結晶体の内部に在る双晶により吸収され、より上方への伝搬を抑制する作用を有する。これに依り、単結晶体の上部に至るまで貫通する貫通転位の密度は減ぜられる。

【００１９】また、そもそもミスフィット転位の少ない単結晶体を得るには、Ｓｉ単結晶基板とリン化硼素系半導体層との中間に緩衝層を設ける技術手段も有効となる。緩衝層は、非晶質または多結晶のリン化硼素系化合物半導体層から構成するのが好適である。非晶質または多結晶の緩衝層は、基板をなすＳｉ単結晶との格子不整合性を緩和して、ミスフィット転位等の結晶欠陥密度の小さいリン化硼素系半導体層をもたらすに効果を発揮する。また、特に、緩衝層をリン化硼素系半導体から構成すると、硼素とリンは成長を促進する「成長核」として作用するため、その上に連続性のあるリン化硼素系半導体層を形成するに効果を奏する。緩衝層をリン化硼素から構成する場合、層厚は約１ｎｍ以上で５０ｎｍ以下、更には２ｎｍ以上で１５ｎｍ以下とするのが好ましい。

【００２０】双晶を含む単結晶体を集合させて構成した多結晶層の表層部は、下方のＳｉ単結晶基板側から貫通して来るミスフィット転位が少なく、結晶性に優れる領域となっている。従って、本発明の構成からなるリン化硼素系半導体多結晶層上には、結晶性に優れる堆積層を成長させることができる。特に、堆積層を、多結晶層の表面をなすリン化硼素系半導体の単結晶体の表面に交差する結晶格子の面間隔（格子間隔）と同一の間隔に配列した結晶面から構成される結晶層とすると、ミスフィット転位の少ない結晶性に優れる結晶層を得るに効果を上げられる。図３に模式的に示す如く、単結晶体の｛１１１｝結晶面からなる表面１７に交差する低次のミラー指数｛ｈｋｌ｝面には、ｈ＝ｋ＝ｌ＝１の｛１１１｝の他、｛１１０｝、｛１００｝結晶面等がある。これら｛ｈｋｌ｝結晶面の単結晶体の｛１１１｝結晶面表面に於ける間隔（＝ｄ）は、立方晶閃亜鉛鉱結晶のリン化硼素系半導体結晶にあっては、$d\,(\text{Å}) = a / \{(h^2+k^2+l^2)^{1/2} \cdot \sin\theta\}$ で与えられる。ａ（Å）はリン化硼素系半導体結晶の格子定数であり、θは｛１１１｝結晶表面１７とそれに交差する結晶面とがなす角度（°）である。例えば、リン化硼素（ＢＰ）多結晶層の表面上に、その表面を構成するＢＰ単結晶体１３の｛１１１｝結晶面と直角に交差する｛１１０｝結晶面と格子間隔（≒３．２１Å）に一致する、六方晶の（１．０．０．０．）結晶面を配列したウルツ鉱結晶型（Ｗｕｒｔｚｉｔｅ）の窒化ガリウム・インジウム混晶（$Ga_{0.94}In_{0.06}N$）結晶層を堆積する例が上げられる。この様な結晶性に優れる結晶層は、例えば、発光素子にあって、高強度の発光をもたらす発光層として好適に利用できる。

【００２１】本発明に係わるリン化硼素系半導体の多結晶層を利用すれば、リン化硼素系半導体素子として例えばＬＥＤを構成できる。ＬＥＤは例えば、ｐ形｛１１１｝−Ｓｉ単結晶基板と、基板上に硼素（Ｂ）とリン（Ｐ）とを含む非晶質の緩衝層を介して成長した本発明に係わるｐ形リン化硼素（ＢＰ）多結晶層と、多結晶層上のｎ形発光層と、発光層上の成長させた本発明に係わるｎ形リン化硼素（ＢＰ）多結晶層とを備えた積層構造体を基に構成できる。室温での禁止帯幅を約３ｅＶとするリン化硼素の単結晶体から構成される多結晶層は、発光層を挟持するクラッド（ｃｌａｄ）層として利用できる。発光層は$Ga_XIn_{1-X}N$（$0 \leqq X \leqq 1$）或いはリン化窒化ガリウム（$GaN_{1-Y}P_Y$：$0 < Y \leqq 1$）等からなる井戸（ｗｅｌｌ）層を備えた単一或いは多重の量子井戸（Ｑｕａｎｔｕｍ Ｗｅｌｌ）構造から構成することもできる。因みに、井戸層に対するバリア（ｂａｒｒｉｅｒ）層は窒化アルミニウム・ガリウム（$Al_XGa_{1-X}N$：$0 \leqq X \leqq 1$）や$GaN_{1-Z}P_Z$（$0 \leqq Z < 1$、$Z < Y$）等から構成できる。上記の積層構造体の表層をなすｎ形リン化硼素多結晶層にｎ形オーミック（Ｏｈｍｉｃ）電極を設け、また、ｐ形Ｓｉ単結晶基板の裏面にｐ形オーミック電極を配置して、ｐｎ接合型ヘテロ構造のＬＥＤを構成できる。

【００２２】また、アンドープ（ｕｎｄｏｐｅ）で高抵抗の｛１１１｝−Ｓｉ単結晶基板と、基板上に硼素（Ｂ）とリン（Ｐ）とを含む多結晶の緩衝層を介して成長した酸素（Ｏ）が添加された高抵抗のリン化硼素多結晶層と、多結晶層上に高純度のｎ形窒化ガリウム（ＧａＮ）層を活性層（電子走行層）として備えた積層構造体からは、ヘテロ接合型の電界効果トランジスタ（ＦＥＴ）等の電子デバイスを構成できる。ＦＥＴは、活性層上にショットキー（Ｓｃｈｏｔｔｋｙ）接合型のゲート（ｇａｔｅ）電極を、また活性層上に積層したｎ形コンタクト層の表面のゲート電極を挟んで対向する位置にソース（ｓｏｕｒｃｅ）及びドレイン（ｄｒａｉｎ）オーミック電極を、それぞれ設けて構成する。

【００２３】

【作用】本発明のリン化硼素系半導体結晶からなる双晶を含む単結晶体は、Ｓｉ単結晶基板とリン化硼素系半導体との格子ミスマッチに起因するミスフィット転位の上方への伝搬を抑制する作用を有する。

【００２４】

【実施例】以下に、｛１１１｝－Ｓｉ単結晶基板上に多結晶層からなるリン化硼素（ＢＰ）層を備えた積層構造体からＬＥＤを作製した例を用いて、本発明を具体的に説明する。

【００２５】本実施例に係わるＬＥＤ１Ｂの平面模式図を図４に示す。また、図４に示す破線Ｘ－Ｘ'に沿ったＬＥＤ１Ｂの断面模式図を図５に示す。

【００２６】ＬＥＤ１Ｂ用途の積層構造体１Ａは、硼素（Ｂ）ドープでｐ形の（１１１）面から2°オフ（ｏｆｆ）した面を有するＳｉ単結晶を基板１０１として構成した。基板１０１上には、トリエチル硼素（$(C_2H_5)_3B$）／ホスフィン（PH_3）／水素（H_2）系常圧ＭＯＣＶＤ法により、３５０℃で、ａｓ－ｇｒｏｗｎ状態で非晶質を主体とするリン化硼素からなる緩衝層１０２を堆積した。緩衝層１０２の層厚は約１０ｎｍとした。

【００２７】緩衝層１０２の表面には、上記のＭＯＣＶＤ気相成長手段を利用して、１０５０℃で多結晶層からなるｐ形のリン化硼素（ＢＰ）層１０３を積層した。成長速度は毎分４０ｎｍに設定した。ｐ形リン化硼素層１０３のキャリア濃度は1×10^{19} cm^{-3}とし、また、層厚は約４００ｎｍとした。ｐ形リン化硼素層１０３の室温での禁止帯幅は大凡、３．０ｅＶであった。

【００２８】透過型電子顕微鏡（ＴＥＭ）を利用した断面ＴＥＭ像と電子線回折図形から、ｐ形リン化硼素層１０３の内部の結晶構造を解析した。図６にＳｉ単結晶基板１０１の＜１１０＞結晶方向に平行に電子線を入射させて得たｐ形リン化硼素層１０３の回折パターンの模写図を示す。図６に示す様に、多結晶層からなるｐ形リン化硼素層１０３をなす各単結晶体１０３ａの｛１１１｝結晶面に由来する回折斑点１９は、＜１１１＞結晶方向に平行に、Ｓｉ単結晶基板１０１の（１１１）結晶面に由来する回折斑点２０に隣接して位置していた。これより、単結晶体１０３ａは、Ｓｉ単結晶基板表面の＜１１１＞結晶方向に平行に、リン化硼素の｛１１１｝結晶面が積重した結晶体であるのが示された。また、図６の回折図形に示す如く、基板１０１のＳｉ単結晶の＜１１１＞結晶方向に整列した単結晶体１０３ａの回折斑点を点対称の中心として、近隣に｛１１１｝結晶面を双晶面とする双晶からの回折斑点２１も確認された。これより、単結晶体１０３ａは｛１１１｝結晶面を双晶面とする双晶を含んでいると確認された。双晶に起因する回折斑点２１の位置から、双晶面はＢＰ結晶の＜１１０＞結晶方向に対し角度にして６０度の方向に存在しているのが示された。

【００２９】ｐ形リン化硼素層１０３の表面には、トリメチルガリウム（$(CH_3)_3Ga$）／トリメチルインジウム（$(CH_3)_3In$／アンモニア（NH_3）／H_2系常圧ＭＯＣＶＤ法により、８５０℃で六方晶のｎ形の窒化ガリウム・インジウム（$Ga_{0.90}In_{0.10}N$）からなる発光層１０４を積層した。発光層１０４の層厚は約１０ｎｍとした。

【００３０】発光層１０４の表面上には、多結晶層からなるアンドープでｎ形のリン化硼素層１０５を積層させた。ｎ形リン化硼素層１０５は、上記のＭＯＣＶＤ気相成長手段を利用して、１０５０℃で積層した。成長速度は毎分３０ｎｍに設定した。ｎ形リン化硼素層１０５は、上記のｐ形リン化硼素層１０３と同様に、ＢＰの（１１１）結晶面からなる正四面体状の単結晶体１０５ａの集合体から構成されるものとなった。ｎ形リン化硼素層のキャリア濃度は8×10^{18} cm^{-3}とし、また、層厚は約３００ｎｍとした。ｎ形リン化硼素層１０５の室温での禁止帯幅は大凡、３．０ｅＶであった。

【００３１】電子線回折図形より、ｎ形リン化硼素層１０５をなす各単結晶体１０５ａの｛１１１｝結晶面は、（１１１）－Ｓｉ単結晶基板１０１の＜１１１＞結晶方向に平行に配列していた。また、単結晶体１０５ａの内部には、ＢＰ結晶の｛１１１｝結晶面を双晶面とする双晶の存在が確認された。双晶面はＢＰ結晶の＜１１０＞結晶方向に対し角度にして６０度の方向に存在した。

【００３２】室温禁止帯幅をおよそ３．０ｅＶとするｐ形リン化硼素層１０３及びｎ形リン化硼素層１０５と、それに同一の格子面間隔を有する材料からなる発光層１０４とからｐｎ接合型ダブルヘテロ（ＤＨ）構造の発光部１０６を構成した。

【００３３】ｎ形リン化硼素層１０５の表面の中央部には、台座電極を兼ねる円形のｎ形オーミック電極１０７を配置した。ｎ形オーミック電極１０７は、金（Ａｕ）・ゲルマニウム（Ｇｅ）合金／ニッケル（Ｎｉ）／金の真空蒸着膜を重層させた多層構造から構成した。ｎ形オーミック電極１０７の直径は約１２０μｍとした。また、ｐ形のＳｉ単結晶基板１０１の裏面の略全面には、ｐ形オーミック電極１０８を配置してＬＥＤ１Ｂを構成した。ｐ形のオーミック電極１０８は、アルミニウム（Ａｌ）真空蒸着膜から構成した。Ｓｉ単結晶基板１０１を［２１１］方向に平行及び垂直な方向に裁断して、一辺を約３００μｍとする正方形のＬＥＤ１Ｂとした。

【００３４】ｎ形オーミック電極１０７に金（Ａｕ）線を結線した後、ｎ形オーミック電極１０７及びｐ形オーミック電極１０８との間に順方向に２０ミリアンペア（ｍＡ）の動作電流を通流して発光特性を調査した。発光中心波長は約４２０ｎｍとなった。発光スペクトルの半値幅（ＦＷＨＭ）は３２ｎｍとなった。本発明では、ミスフィット転位の密度の低いｐ形リン化硼素層１０３を下地層として発光層１０４を形成する構成としたため、発光領域には非発光の暗線（ｄａｒｋ ｌｉｎｅ）（米津、宏雄著、「光通信素子工学－発光・受光素子」（平成７年５月２０日、工学図書（株）発行５版、１５５～１５６頁参照）は視認されず、発光領域の全面から略均等の強度の発光がもたらされた。このため、一般的な積分球を利用して測定されるチップ（ｃｈｉｐ）状態

での輝度は８ミリカンデラ（ｍｃｄ）となり、高発光強度のＬＥＤが提供されることとなった。また、ＬＥＤ１Ｂの電流－電圧（Ｉ－Ｖ）特性には、転位の影響に因る局所的な耐圧不良（ｌｏｃａｌｂｒｅａｋｄｏｗｎ）の発生は認められず、本発明の構成からは、良好なｐｎ接合特性（整流性）を呈するｐｎ接合型の発光部１０６がもたらされることが示された。Ｉ－Ｖ特性から求めた順方向電圧（所謂、Ｖｆ）は３．６Ｖ（順方向電流＝２０ｍＡ）で、また、逆方向電圧は６Ｖ（逆方向電流＝１０μＡ）であり、高耐圧であるＬＥＤが提供された。

【００３５】

【発明の効果】本発明では、表面を｛１１１｝－結晶面とするＳｉ単結晶基板上に設けるリン化硼素系半導体層を、ミスフィット転位を吸収して、転位の伝搬を抑制できる双晶を含む単結晶体を集合させた多結晶層から構成することとしたので、転位密度の少ない結晶性に優れるリン化硼素系半導体層を構成することができ、これを利用すれば特性に優れるリン化硼素系半導体素子、例えば、発光強度、整流性及び耐圧性に優れるリン化硼素系半導体発光素子を提供できる効果がある。

【図面の簡単な説明】

【図１】本発明に係る多結晶層を構成する単結晶体の形状を示す模式図である。

【図２】本発明に係る多結晶層の構成を示す平面模式図である。

【図３】本発明に係るリン化硼素系半導体層の｛１１１｝結晶面に交差する結晶面を表す模式図である。

【図４】本発明の実施例に係るＬＥＤの平面模式図である。

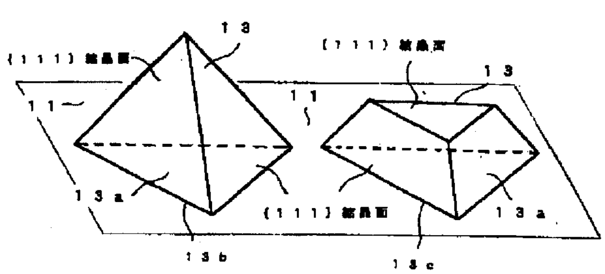
【図５】図３の破線Ｘ－Ｘ’に沿ったＬＥＤの断面模式図である。

【図６】本発明の実施例に係るリン化硼素層の電子線回折パターンの模写図である。

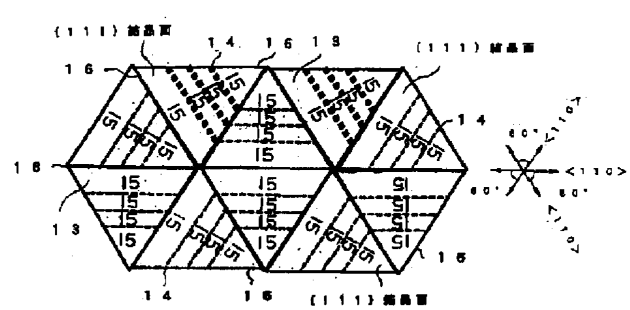
【符号の説明】

１Ａ　積層構造体
１Ｂ　ＬＥＤ
１１　Ｓｉ単結晶基板
１２　リン化硼素系半導体多結晶層
１３　単結晶体
１３ａ　単結晶体の底面
１４　双晶面
１５　双晶
１６　単結晶体の接合面
１７　単結晶体の｛１１１｝結晶面
１８　｛ｈｋｌ｝面
１９　リン化硼素単結晶体の回折スポット
２０　Ｓｉ単結晶基板の回折スポット
２１　双晶の回折スポット
１０１　Ｓｉ単結晶基板
１０２　緩衝層
１０３　ｐ形リン化硼素層
１０３ａ　単結晶体
１０４　発光層
１０５　ｎ形リン化硼素層
１０５ａ　単結晶体
１０６　発光部
１０７　ｎ形オーミック電極
１０８　ｐ形オーミック電極

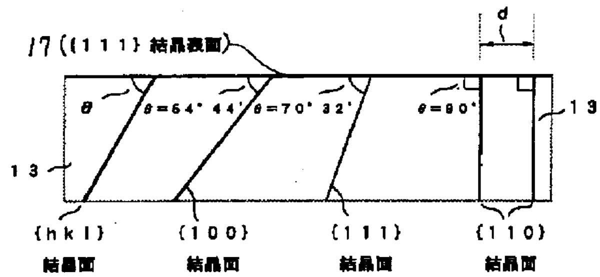
【図１】



【図２】



【図３】



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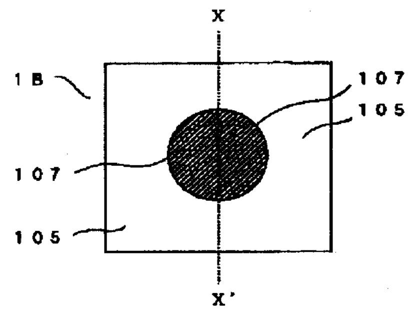

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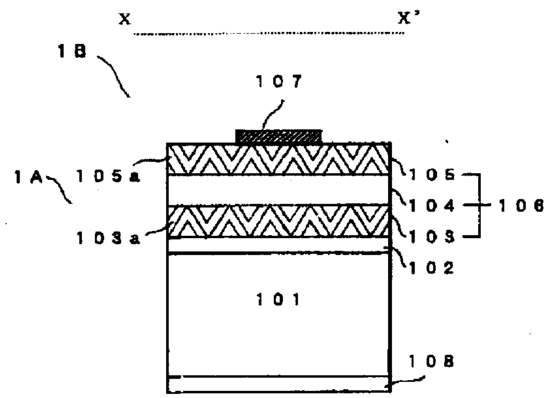
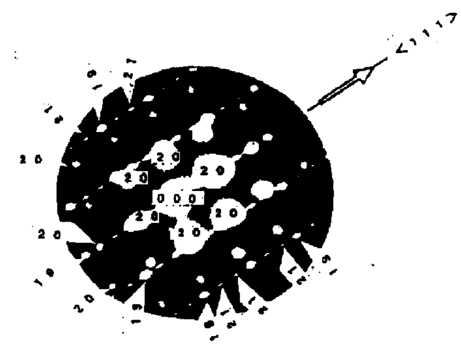


【図６】



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PATENT ABSTRACTS OF JAPAN

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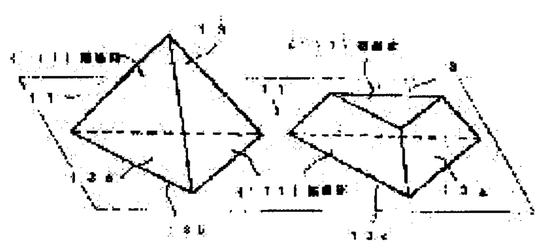
(22)Date of filing :	04.02.2002	(72)Inventor :	YAMASHITA TAKASHI UDAGAWA TAKASHI

(54) BORON PHOSPHIDE TYPE SEMICONDUCTOR DEVICE, METHOD OF MANUFACTURING IT, LIGHT-EMITTING DIODE AND BORON PHOSPHIDE TYPE SEMICONDUCTOR LAYER

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a boron phosphide type semiconductor device, in which a characteristic is advanced, providing a polycrystalline boron phosphide type semiconductor layer stably including twins which have twin faces having specific crystal directions.
SOLUTION: A substrate is formed with (111) Si single crystals having surfaces constructed with (111) crystal faces, a laminated boron phosphide type semiconductor layer is constructed with a polycrystal layer in which a plurality of single crystal body, which has a bottom face formed with (111) the crystal face and also is surrounded by a face equivalent to (111) the crystal face, constructed with square spindle shape boron phosphide type semiconductor crystals are got together; further, the single crystal body has a twin boundary surface having a tilt angle of 60 degrees against (110) a crystal orientation of the substrate.



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CLAIMS

[Claim(s)]

[Claim 1] Were formed on the front face of the substrate which consists of a silicon (Si) single crystal, and this substrate. In the Lynn-ized boron system semiconductor device equipped with the Lynn-ized boron system semi-conductor layer which consists of a Lynn-ized boron system semiconducting crystal which has the same crystal face as the crystal face which constitutes the front face of a substrate The aforementioned substrate consists of a {111}-Si single crystal which makes a front face the {111} crystal faces. The aforementioned Lynn-ized boron system semi-conductor layer It has the base which consists of the {111} crystal faces of the Lynn-ized boron system semiconducting crystal arranged in parallel with the {111} crystal faces of a substrate. And it consists of polycrystal layers which were surrounded in respect of being equivalent to the {111} crystal faces and which gathered the single crystal object of the Lynn-ized boron system semiconducting crystal of the shape of two or more square spindle. The Lynn-ized boron system semiconductor device characterized by furthermore having the twin boundary side to which this single crystal object inclined at the include angle of 60 degrees to the <110> crystal orientation of a substrate.

[Claim 2] The Lynn-ized boron system semiconductor device according to claim 1 characterized by to consist of the crystal faces arranged at spacing whose group-III-V-semiconducter layer of this has the different-species (hetero) junction in which the laminating of the group-III-V-semiconducter layer was carried out, and it was formed on said Lynn-ized boron system semi-conductor layer, and corresponds with the spacing (lattice spacing) of the crystal face which intersects the front face of the single crystal object which makes the Lynn-ized boron system semi-conductor layer.

[Claim 3] The Lynn-ized boron system semiconductor device according to claim 1 or 2 characterized by the single crystal object of said Lynn-ized boron system semiconducting crystal consisting of a Lynn-ized boron (boron monophosphide) crystal of a monomer.

[Claim 4] The manufacture approach of claim 1 characterized by forming a growth rate for said Lynn-ized boron system semi-conductor layer as 20nm [or more]/m 60nm or less by organic metal pyrolysis vapor growth (MOCVD law) in 950-degree-C or more temperature of 1100 degrees C or less on a {111}-Si single crystal substrate thru/or the Lynn-ized boron system semiconductor device given in 3.

[Claim 5] The manufacture approach of the Lynn-ized boron system semiconductor device according to claim 4 characterized by forming a growth rate for said Lynn-ized boron system semi-conductor layer as 30nm [or more]/m 40nm or less by organic metal pyrolysis vapor growth (MOCVD law) in 1025-degree-C or more temperature of 1075 degrees C or less on a {111}-Si single crystal substrate.

[Claim 6] Light emitting diode set to claim 1 thru/or 3 from the Lynn-ized boron system semiconductor device of a publication.

[Claim 7] In the Lynn-ized boron system semi-conductor layer which consists of a Lynn-ized boron system semiconducting crystal which was formed on the front face of the substrate which consists of a silicon (Si) single crystal, and which has the same crystal face as the crystal face which constitutes the front face of a substrate The aforementioned substrate consists of a {111}-Si single crystal which makes a front face the {111} crystal faces. The aforementioned Lynn-ized boron system semi-conductor layer It has the base which consists of the {111} crystal faces of the Lynn-ized boron system semiconducting crystal arranged in parallel with the {111} crystal faces of a substrate. And it consists of polycrystal layers which were surrounded in respect of being equivalent to the {111} crystal faces and which gathered the single crystal object of the Lynn-ized boron system semiconducting crystal of the shape of two or more square spindle. The Lynn-ized boron system semi-conductor layer characterized by furthermore having the twin boundary side to which this single crystal object inclined at the include angle of 60 degrees to the <110> crystal orientation of a substrate.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the crystal configuration of the Lynn-ized boron system semi-conductor layer which becomes suitable to obtain the Lynn-ized boron system semiconductor device formed on (Silicon Si) single crystal (silicon) substrate, and the Lynn-ized boron system semiconductor device possessing it.
[0002]
[Description of the Prior Art] It is in the former and the technique which forms semi-conductor light emitting devices, such as light emitting diode (LED) or a laser diode (LD), using the Lynn-ized boron (BP) which is a kind of the Lynn-ized boron system semi-conductor which contains boron (B) and Lynn (P) as a configuration element is found (refer to United States patent No. 6,069,021). The conventional Lynn-ized boron system semi-conductor light emitting device is constituted using the laminating structure which contains the Lynn-ized boron layer formed on the substrate which consists for example, of a silicon single crystal (silicon) as a buffer coat (refer to above-mentioned United States patent No. 6,069,021). Recently, the laminating structure of the semi-conductor light emitting device application equipped with the light-emitting part is also invented in the pn junction mold duplex hetero structure which uses the Lynn-ized boron layer of a wideband gap as an obstruction (clad) layer (refer to application for patent No. 158282 [2001 to]).
[0003] Conventionally, on a silicon substrate, it has become clear that the single crystal layer of Lynn-ized boron which consists of the same crystal face as the crystal face which makes a substrate front face grows. For example, it is found that the Lynn-ized boron single crystal layer which consists of the {100} crystal faces accumulated in parallel with a substrate front face on the {100}-Si single crystal substrate which makes a front face the {100} crystal faces grows (Katsufusa Shono work, "semiconductor technology (above)" (refer to June 25, 1992, the 9th ** of the University of Tokyo Press issue, and 77 pages).). Moreover, on the silicon substrate, it is also found that the Lynn-ized boron single crystal layer which does not contain twin crystal (twinning) at all can grow (refer to the above-mentioned "the semiconductor technology (above)" and 98 pages). On the other hand, it is found that the {100}-Lynn-ized boron single crystal layer containing twin crystal is also obtained (refer to the above-mentioned "the semiconductor technology (above)" and 99 - 100 pages).
[0004]
[Problem(s) to be Solved by the Invention] When the conventional technique indicates, the twin crystal contained in the Lynn-ized boron layer is supposed that it has the description which eases the rate of mismatching between crystal lattices (refer to the above-mentioned "the semiconductor technology (above)" and 100 pages). Therefore, if the Lynn-ized boron system semi-conductor layer containing twin crystal is used, it can contribute for obtaining LED which is excellent in a property, for example, luminescence reinforcement. However, it is difficult to be stabilized and to obtain the Lynn-ized boron system semi-conductor layer containing twin crystal so that the conventional technique may indicate. That is, since the requirements for manufacturing conventionally the Lynn-ized boron system semi-conductor layer which is stabilized and contains twin crystal are not **, trouble has been caused to it being stabilized and gaining the light emitting device which is excellent in the reinforcement of luminescence.
[0005] This invention aims at offering the Lynn-ized boron system semi-conductor layer which consists of a crystal configuration in which it can be stabilized and twin crystal can be included. Moreover, in this invention, the Lynn-ized boron system semiconductor device whose property improved is offered by having the Lynn-ized boron system semi-conductor layer of the polycrystal which is stabilized and contains the twin crystal which makes specific crystal orientation a twin plane. The Lynn-ized boron system semi-conductor layer which consists of the crystal structure made into the purpose of this invention here is a twin boundary side (twin plane) (C. it is the Lynn-ized boron system semi-conductor layer which consists of polycrystal which makes W. van work and the single crystal object which is different in the crystal orientation of "chemical crystallography" (refer to June 15, Showa 45, Baifukan Issue First edition, and 75-76 pages) come to gather.) rather than consists of a single crystal of the shape of conventional film.
[0006]
[Means for Solving the Problem] Namely, this invention was formed on the front face of the substrate which consists of a (1) silicon (Si) single crystal, and this substrate. In the Lynn-ized boron system semiconductor device equipped with the Lynn-ized boron system semi-conductor layer which consists of a Lynn-ized boron

system semiconducting crystal which has the same crystal face as the crystal face which constitutes the front face of a substrate The aforementioned substrate consists of a {111}-Si single crystal which makes a front face the {111} crystal faces. The aforementioned Lynn-ized boron system semi-conductor layer It has the base which consists of the {111} crystal faces of the Lynn-ized boron system semiconducting crystal arranged in parallel with the {111} crystal faces of a substrate. And it consists of polycrystal layers which were surrounded in respect of being equivalent to the {111} crystal faces and which gathered the single crystal object of the Lynn-ized boron system semiconducting crystal of the shape of two or more square spindle. The Lynn-ized boron system semiconductor device characterized by furthermore having the twin boundary side to which this single crystal object inclined at the include angle of 60 degrees to the <110> crystal orientation of a substrate. It comes out.

[0007] moreover, this invention -- (2) -- a Lynn-ized boron system semiconductor device given in the above (1) characterized by to consist of the crystal faces which arranged at spacing whose group-III-V-semiconducter layer of this has the different-species (hetero) junction in which the laminating of the group-III-V-semiconducter layer was carried out, and it was formed on said Lynn-ized boron system semi-conductor layer, and corresponds with the spacing (a lattice spacing) of the crystal face which intersects the front face of the single crystal object which makes the Lynn-ized boron system semi-conductor layer. (3) The above (1) characterized by the single crystal object of said Lynn-ized boron system semiconducting crystal consisting of a Lynn-ized boron (boron monophosphide) crystal of a monomer, or the Lynn-ized boron system semiconductor device given in (2).

[0008] moreover, this invention -- (4) -- the manufacture approach of the Lynn-ized boron system semiconductor device the above (1) characterized by forming a growth rate for said Lynn-ized boron system semi-conductor layer as 20nm [or more]/m 60nm or less by organic metal pyrolysis vapor growth (MOCVD law) in 950-degree-C or more temperature of 1100 degrees C or less on a {111}-Si single crystal substrate thru/or given in (3). (5) The manufacture approach of the Lynn-ized boron system semiconductor device given in the above (4) characterized by forming a growth rate for said Lynn-ized boron system semi-conductor layer as 30nm [or more]/m 40nm or less by organic metal pyrolysis vapor growth (MOCVD law) in 1025-degree-C or more temperature of 1075 degrees C or less on a {111}-Si single crystal substrate. It comes out.

[0009] Moreover, this invention is light emitting diode set to (6) above (1) thru/or (3) from the Lynn-ized boron system semiconductor device of a publication. It comes out.

[0010] Moreover, this invention was formed on the front face of the substrate which consists of a (7) silicon (Si) single crystal. In the Lynn-ized boron system semi-conductor layer which consists of a Lynn-ized boron system semiconducting crystal which has the same crystal face as the crystal face which constitutes the front face of a substrate The aforementioned substrate consists of a {111}-Si single crystal which makes a front face the {111} crystal faces. The aforementioned Lynn-ized boron system semi-conductor layer It has the base which consists of the {111} crystal faces of the Lynn-ized boron system semiconducting crystal arranged in parallel with the {111} crystal faces of a substrate. And it consists of polycrystal layers which were surrounded in respect of being equivalent to the {111} crystal faces and which gathered the single crystal object of the Lynn-ized boron system semiconducting crystal of the shape of two or more square spindle. The Lynn-ized boron system semi-conductor layer characterized by furthermore having the twin boundary side to which this single crystal object inclined at the include angle of 60 degrees to the <110> crystal orientation of a substrate. It comes out.

[0011]

[Embodiment of the Invention] In this invention, the Lynn-ized boron system semi-conductor layer can be formed suitably on Si single crystal substrate (this specification indicates a {111}-Si single crystal substrate.) which uses the {111} crystal faces as a front face. The silicon atom exists in the {111} crystal faces of Si single crystal of a diamond (diamond) crystal structure mold more densely than {100} or the {110} crystal faces. Therefore, in a {111}-Si single crystal substrate, there is an advantage which can control diffusion inside [of the configuration element of the Lynn-ized boron system semi-conductor layer deposited on it] a substrate and osmosis, and effect is taken in constituting a clear junction interface. The rear-face electrode of positive/negative and which polar ohmic (Ohmic) nature electrode is carried out to a rear face, and they can be laid at it, for example, effectiveness can be raised in the {111}-Si single crystal substrate which has conductivity for constituting a light emitting device simple again. The low conductive single crystal substrate of specific resistance (resistivity) which makes resistivity especially more desirably less than [0.1mohm] contributes for bringing about LED with low forward voltage (the so-called Vf) below 1 milli ohm (mohms). Moreover, it becomes effective in constituting LD which brings about the oscillation stabilized since it excelled in heat dissipation nature.

[0012] Let the Lynn-ized boron system semi-conductor layer of the polycrystal layer which carries out a laminating on a {111}-Si substrate front face preferably be for example, the BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaAsdelta layer (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0< alpha+beta+gamma <=1, 0<=delta<1) which contains boron (B) and Lynn (P) as a configuration element. Moreover, for example, it constitutes from BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaNdelta (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0< alpha+beta+gamma <=1, 0<=delta<1). A configuration element is boron (B) and Lynn (P), and especially since the Lynn-ized boron (boron monophosphide:BP) of a monomer has the advantage that there are few configuration elements than plural mixed crystal, and membrane formation is

easy, it is desirable. Moreover, the Lynn-ized boron which depended on the organic metal pyrolysis vapor growth (MOCVD) means, set the growth rate to 30nm or less at 2nm [or more]/m, for example, and grew the supply ratio (the so-called V/III ratio) of the raw material of V group elements, such as Lynn, and III group elements, such as boron, as 60 or less range or more by 15 serves as a wideband gap (wide bandgap) semi-conductor which sets the band gap in a room temperature to about 3eV. The large Lynn-ized boron semi-conductor layer of such a band gap is in a light emitting device, and can be used as an obstruction (clad) layer to a luminous layer.

[0013] The Lynn-ized boron system semi-conductor layer of a polycrystal layer gathers the single crystal object which consists of two or more Lynn-ized boron system semiconducting crystals, and constitutes it from this invention. The configuration of the single crystal object which constitutes the polycrystal layer concerning this invention is typically shown in drawing 1 . Each single crystal object 13 on the {111}-Si single crystal substrate 11 is making the appearance of square cone 13c which makes the crowning of forward square pyramid-of-medulla-oblongata 13b which makes a perimeter a field equivalent to the {111} crystal faces of the Lynn-ized boron system semiconducting crystal, or a forward square pyramid of medulla oblongata the {111} crystal faces. Base 13a of each single crystal object 13 consists of the {111} crystal faces of the Lynn-ized boron system semiconducting crystal arranged in parallel with the {111} crystal faces of a {111}-Si single crystal substrate. Base 13a is the crystal face grounded on the front face of the {111}-Si single crystal substrate 11.

[0014] As shown in the mimetic diagram of drawing 2 , the polycrystal layer of this invention combines the single crystal object 13 of two or more shape of an above square drill mutually, and is constituted. Each single crystal object 13 of each other is connected through a plane of composition 16. Twin crystal 15 is made to have existed in the interior of each single crystal object 13. Since the direction where the twin plane 14 included inside each single crystal object 13 exists is not uniformly fixed, the Lynn-ized boron system semi-conductor layer which consists of each single crystal objects 13 which contain twin crystal in such different crystal orientation has been called the polycrystal layer by this invention. The single crystal object 13 in which it was made the include angle to the <110> crystal orientation of a {111}-Si single crystal which makes a substrate, and the twin plane was regularly included in the direction of 60 degrees (degree) is gathered, and a polycrystal layer consists of especially this inventions. Specifically, the twin plane as used in the field of here is a field equivalent to the {111} crystal faces of the Lynn-ized boron system semiconducting crystal. Namely, {111} {-1.-1.-1.} {1. They are the crystal faces, such as -1.1.}. Moreover, it is the description that a twin plane is parallel to which the {111} crystal faces of the Lynn-ized boron system semiconducting crystal which constitutes the perimeter of the square spindle-like single crystal object 13. It is based on generating of the twin crystal 15 which makes the {111} crystal faces of the Lynn-ized boron system semiconducting crystal a twin plane 14, and generating of the mistake mitt (misfit) rearrangement resulting from the lattice mismatch of Si single crystal substrate and the Lynn-ized boron system semiconducting crystal and propagation can be controlled effectively. In the Lynn-ized boron system semiconducting crystal. the twin crystal which makes the {111} crystal faces a twin plane is stabilized as compared with the twin crystal which makes other crystal faces a twin plane, and can be formed easily. Therefore, effect can be demonstrated for it to be stabilized and control propagation of a misfit rearrangement, if the single crystal object containing the twin crystal which makes a twin plane the {111} crystal faces of the Lynn-ized boron system semiconducting crystal is gathered and a polycrystal layer is constituted.

[0015] Existence of twin crystal is found from the existence of the abnormality diffraction mottle (spot) on the electron diffraction graphic form (pattern) picturized by for example, electron diffraction technique (refer to hill ******, "crystal electron microscope study", November 25, 1997, the 1st Edition of Uchida Rokakuho Publishing Issue, and 111 - 113 pages). Moreover, if the include angle of the <110> crystal orientation on the diffraction pattern which picturized the incidence electron ray as parallel to the <110> crystal orientation of the Lynn-ized boron system semi-conductor layer, and the diffraction mottle resulting from twin crystal to make is measured, the include angle which <110> crystal orientation and twin crystal make can be known. Incidentally, it can also be considered that twin crystal is a kind of stacking fault (stacking fault) again (refer to the above-mentioned "crystal electron microscope study" and 112 pages).

[0016] In order to obtain the polycrystal layer which gathered the single crystal object containing the twin crystal concerning this invention, it is necessary to control the conditions at the time of membrane formation to a precision. Especially the single crystal object of the shape of a square spindle which consists of a Lynn-ized boron system semiconducting crystal containing the twin crystal which makes the {111} crystal faces a twin plane controls and forms growth temperature in a precision by the organic metal pyrolysis vapor growth (MOCVD law) of the ordinary pressure which makes for example, boron triethyl (C2H5) (3B) / phosphine (PH3) / hydrogen (H2) a raw material system. It is in the above-mentioned MOCVD means, and the range of the Lynn-ized boron system semi-conductor polycrystal layer and especially the range of 950 degrees C or more 1100 degrees C or less of suitable temperature to obtain the polycrystal layer of the Lynn-ized boron of a monomer is 1025 degrees C - 1075 degrees C still more preferably. About 950 degrees C - about 1000 degrees C of low temperature are more suitable for formation of the Lynn-ized boron system semi-conductor polycrystal layer containing an indium (In). About 1050 degrees C - hot 1100 degrees C are suitable for the Lynn-ized boron system semi-conductor polycrystal layer which contains aluminum (aluminum) as a configuration element in comparison. At the elevated temperature exceeding about 1200 degrees C, it

becomes easy to generate the Lynn-ized boron polymer of BP6 and B13P2 grade, and becomes inconvenient for obtaining the Lynn-ized boron system semi-conductor layer homogeneous in presentation.
[0017] Moreover, in order to form efficiently the single crystal object which is inherent in twin crystal, it is desirable to make the rate of growth into the range of 20 to 60nm/m. [/m] If it is in the Lynn-ized boron (BP) of a monomer, especially a rate with a growth of 30nm/m - 40nm is suitable. It produces un-arranging [which the consistency of other crystal defects, such as a point defect and a rearrangement, increases to the single crystal object grown up at the rate exceeding 60nm rapidly in addition to a lot of twin crystal (stacking fault)], and difficulty is caused to obtaining the polycrystal layer which is excellent in crystallinity. On the contrary, if a growth rate is made small (i.e., if it is the situation of requiring long duration more for obtaining the Lynn-ized boron system semi-conductor layer of desired thickness), the opportunity for Lynn (P) of a configuration element to vaporize at the time of growth will increase. For this reason, the imbalance of the chemical equivalent ratio between evaporation of Lynn (P) and the configuration element of the Lynn-ized boron system semi-conductor layer resulting from vaporization generates the small growth rate of the following rapidly by 20nm/. Since the point defect is included in the Lynn-ized boron system compound semiconductor layer of a presentation out of balance to stoichiometric so much, for considering as the polycrystal layer concerning this invention, it is unsuitable.
[0018] The twin crystal contained inside a single crystal object has the operation which controls propagation of the misfit rearrangement which originates in the lattice mismatch of Si single crystal of a substrate, and the Lynn-ized boron system semi-conductor which constitutes a single crystal object, and is generated. For example, the misfit rearrangement generated from the junction interface of Si substrate and a single crystal object is absorbed with the twin crystal in the interior of a single crystal object, and has the operation which controls the propagation to the upper part. It depends on this and the consistency of the penetration rearrangement penetrated until it reaches the upper part of a single crystal object is reduced.
[0019] Moreover, in order to acquire a single crystal object with few misfit rearrangements primarily, a technical means to prepare a buffer coat in the middle of Si single crystal substrate and the Lynn-ized boron system semi-conductor layer also becomes effective. It is suitable for a buffer coat to constitute from a Lynn-ized boron system compound semiconductor layer of an amorphous substance or polycrystal. The buffer coat of an amorphous substance or polycrystal eases stacking fault affinity with Si single crystal which forms a substrate, and demonstrates effectiveness to bring about the Lynn-ized boron system semi-conductor layer with small crystal defect consistencies, such as a misfit rearrangement. Moreover, if a buffer coat is especially constituted from a Lynn-ized boron system semi-conductor, boron and Lynn will take effect to form the Lynn-ized boron system semi-conductor layer which has a continuity on it in order to act as a "growth nucleus" which promotes growth. When it constitutes a buffer coat from Lynn-ized boron, as for thickness, it is desirable that it is referred to as 50nm or less by about 1nm or more, and it refers to to 15nm or less by 2 morenm or more.
[0020] The surface section of the polycrystal layer which the single crystal object containing twin crystal was gathered, and constituted it has few mistake FITO rearrangements penetrated from downward Si single crystal substrate side, and it has become the field which is excellent in crystallinity. Therefore, the deposit which is excellent in crystallinity can be grown up on the Lynn-ized boron system semi-conductor polycrystal layer which consists of a configuration of this invention. If it is the crystal layer which consists of the crystal faces which arranged the deposit especially at the same spacing as the spacing (lattice spacing) of the crystal lattice which intersects the front face of the single crystal object of the Lynn-ized boron system semi-conductor which makes the front face of a polycrystal layer, effectiveness can be raised for obtaining the crystal layer which is excellent in crystallinity with few misfit rearrangements. As typically shown in drawing 3 , the h=k=l= {110} and {100} crystal face etc. is located in the Miller-indices {hkl} side of a low degree which intersects the front face 17 which consists of the {111} crystal faces of a single crystal object. [besides {111} of 1] If spacing (=d) in the {111} crystal-face front face of the single crystal object of these {hkl} crystal faces is in the Lynn-ized boron system semiconducting crystal of a cubic sphalerite crystal, it is given by d(A) =a/{(h2+k2+l2) 1/2, andsintheta}. a (A) is the lattice constant of the Lynn-ized boron system semiconducting crystal, and theta is an include angle (degree) which the crystal face which intersects the {111} crystal front face 17 and it makes. For example, the example which deposits the gallium nitride indium mixed-crystal (Ga0.94In0.06N) crystal layer of the wurtzite crystal mold (Wurtzite) which arranged the {110} crystal faces which intersect the {111} crystal faces and the right angle of BP single crystal object 13 which constitutes the front face, and the hexagonal (1.0.0.0.) crystal face which is in agreement with a lattice spacing (**3.21A) is raised on the front face of a Lynn-ized boron (BP) polycrystal layer. The crystal layer which is excellent in such crystallinity is in a light emitting device, and can be suitably used as a luminous layer which brings about luminescence of high intensity.
[0021] If the polycrystal layer of the Lynn-ized boron system semi-conductor concerning this invention is used, LED can be constituted as a Lynn-ized boron system semiconductor device. LED can be constituted based on the laminating structure equipped with for example, the p form {111}-Si single crystal substrate, the p form Lynn-ized boron (BP) polycrystal layer concerning this invention which grew through the amorphous buffer coat containing boron (B) and Lynn (P) on the substrate, n form luminous layer on a polycrystal layer, and the n form Lynn-ized boron (BP) polycrystal layer concerning this invention grown up on the luminous layer. The polycrystal layer which consists of single crystal objects of the Lynn-ized boron which sets the

band gap in a room temperature to about 3eV can be used as a clad (clad) layer which pinches a luminous layer. A luminous layer can also consist of singles or multiplex quantum well (Quantum Well) structures equipped with the well (well) layer which consists of GaXIn1-XN (0<=X<=1) or Lynn-ized gallium nitride (GaN1-YPY:0<Y<=1). Incidentally, the barrier (barrier) layer to a well layer can consist of an alumimium nitride gallium (AlXGa1-XN:0 <=X<=1), GaN1-ZPZ (0<=Z<1, Z<Y), etc. n form ohmic (Ohmic) electrode is prepared in n form Lynn-ized boron polycrystal layer which makes the surface of the above-mentioned laminating structure, and p form ohmic electrode is arranged at the rear face of a p form Si single crystal substrate, and LED of pn junction mold hetero structure can be constituted.

[0022] Moreover, the {111}-Si single crystal substrate of the high resistance in undoping (undope), The Lynn-ized boron polycrystal layer of high resistance by which the oxygen (O) which grew through the buffer coat of the polycrystal containing boron (B) and Lynn (P) on the substrate was added, Electron devices, such as a field-effect transistor (FET) of a heterojunction mold, can consist of the laminating structures equipped with n form gallium nitride (GaN) layer of a high grade as a barrier layer (electronic transit layer) on the polycrystal layer. FET -- a barrier layer top -- the gate (gate) electrode of a shot key (Schottky) assembling die -- moreover, in the location which counters on both sides of the gate electrode of the front face of n form contact layer which carried out the laminating on a barrier layer, the source (source) and a drain (drain) ohmic electrode are prepared, respectively, and are constituted.

[0023]

[Function] The single crystal object containing the twin crystal which consists of a Lynn-ized boron system semiconducting crystal of this invention has the operation which controls the propagation to the upper part of the misfit rearrangement resulting from the lattice mismatch of Si single crystal substrate and the Lynn-ized boron system semi-conductor.

[0024]

[Example] Below, this invention is concretely explained using the example which produced LED from the laminating structure equipped with the Lynn-ized boron (BP) layer which consists of a polycrystal layer on the {111}-Si single crystal substrate.

[0025] The mimetic diagram of LED1B concerning this example is shown in drawing 4 . Moreover, the cross section of LED1B in alignment with broken-line X-X' shown in drawing 4 is shown in drawing 5 .

[0026] Laminating structure 1A of an LED1B application constituted Si single crystal which has the field which carried out 2-degree OFF (off) from the field (111) of p form from a boron (B) dope as a substrate 101. a substrate 101 top -- boron triethyl (C2H5) (3B) / phosphine (PH3) / hydrogen (H2) system ordinary pressure MOCVD -- the buffer coat 102 which consists of Lynn-ized boron which makes an amorphous substance a subject in the state of as-grown at 350 degrees C by law was deposited. The thickness of a buffer coat 102 could be about 10nm.

[0027] The laminating of the Lynn-ized boron (BP) layer 103 of p form which consists of a polycrystal layer at 1050 degrees C was carried out to the front face of a buffer coat 102 using the above-mentioned MOCVD vapor growth means. The growth rate was set as 40nm/m. Carrier concentration of p form Lynn-ized boron layer 103 was set to 1x1019cm-3, and thickness could be about 400nm. The band gap in the room temperature of p form Lynn-ized boron layer 103 was 3.0eV about.

[0028] From the cross-section TEM image using a transmission electron microscope (TEM), and the electron diffraction graphic form, the crystal structure inside p form Lynn-ized boron layer 103 was analyzed. The copy Fig. of the diffraction pattern of p form Lynn-ized boron layer 103 which was made to carry out incidence of the electron ray to drawing 6 in parallel with the <110> crystal orientation of Si single crystal substrate 101, and was obtained is shown. drawing 6 -- being shown -- as -- polycrystal -- a layer -- from -- becoming -- p -- a form -- Lynn ---izing -- boron -- a layer -- 103 -- making -- each -- a single crystal -- the body -- 103 -- a -- {-- 111 --} -- the crystal face -- originating -- a diffraction mottle -- 19 -- < -- 111 -- > -- crystal orientation -- parallel -- Si -- a single crystal -- a substrate -- 101 -- the crystal face (111) -- originating -- a diffraction mottle -- 20 -- adjoining -- being located -- **** . From this, it was shown that single crystal object 103a is the crystalline which the {111} crystal faces of Lynn-ized boron accumulated in parallel with the <111> crystal orientation of Si single crystal substrate front face. Moreover, as shown in the diffraction pattern of drawing 6 , the diffraction mottle 21 from the twin crystal which makes the {111} crystal faces a twin plane in the neighborhood was also checked considering the diffraction mottle of single crystal object 103a which aligned at the <111> crystal orientation of Si single crystal of a substrate 101 as a core of point symmetry. From this, when single crystal object 103a contained the twin crystal which makes the {111} crystal faces a twin plane, it was checked. From the location of the diffraction mottle 21 resulting from twin crystal, making a twin plane into an include angle to the <110> crystal orientation of BP crystal, and existing in the direction of 60 degrees was shown.

[0029] the front face of p form Lynn-ized boron layer 103 -- trimethylgallium (CH3) (3Ga)/trimethylindium (CH3) (3In / ammonia (NH3) / H-2 system ordinary pressure MOCVD -- by law, the laminating of the luminous layer 104 which consists of a gallium nitride indium (Ga0.90In0.10N) of hexagonal n form at 850 degrees C was carried out.) The thickness of a luminous layer 104 could be about 10nm.

[0030] On the front face of a luminous layer 104, the laminating of the Lynn-ized boron layer 105 of n form was carried out by undoping which consists of a polycrystal layer. The laminating of the n form Lynn-ized boron layer 105 was carried out at 1050 degrees C using the above-mentioned MOCVD vapor growth means.

The growth rate was set as 30nm/m. n form Lynn-ized boron layer 105 became what consists of the aggregates of single crystal object 105a of the shape of a regular tetrahedron which consists of the crystal face (111) of BP like the above-mentioned p form Lynn-ized boron layer 103. Carrier concentration of n form Lynn-ized boron layer was set to 8x1018cm-3, and thickness could be about 300nm. The band gap in the room temperature of n form Lynn-ized boron layer 105 was 3.0eV about.
[0031] From the electron diffraction graphic form, the {111} crystal faces of each single crystal object 105a which makes n form Lynn-ized boron layer 105 were arranged in parallel with the <111> crystal orientation of the (111)-Si single crystal substrate 101. Moreover, inside single crystal object 105a, existence of the twin crystal which makes the {111} crystal faces of BP crystal a twin plane was checked. The twin plane was made into the include angle to the <110> crystal orientation of BP crystal, and existed in the direction of 60 degrees.
[0032] The light-emitting part 106 of pn junction mold double hetero (DH) structure consisted of p form Lynn-ized boron layer 103 and n form Lynn-ized boron layer 105 which set a room temperature band gap to about 3.0eV, and a luminous layer 104 which becomes it from the ingredient which has the same lattice spacing.
[0033] In the center section of the front face of n form Lynn-ized boron layer 105, circular n form ohmic electrode 107 which serves as a plinth electrode has been arranged. n form ohmic electrode 107 constituted the vacuum deposition film of golden (Au) and (Germanium germanium) alloy / (nickel nickel) / gold from multilayer structure which carried out multistory. The diameter of n form ohmic electrode 107 was set to about 120 micrometers. Moreover, all over the abbreviation for the rear face of Si single crystal substrate 101 of p form, p form ohmic electrode 108 has been arranged and LED1B was constituted. The ohmic electrode 108 of p form consisted of (Aluminum aluminum) vacuum deposition film. Si single crystal substrate 101 was cut out in the direction parallel to the [211] directions, and perpendicular, and it was referred to as LED1B of the square which sets one side to about 300 micrometers.
[0034] After connecting a golden (Au) line to n form ohmic electrode 107, conduction of the operating current of 20mA (mA) was carried out in the forward direction between n form ohmic electrode 107 and p form ohmic electrode 108, and the luminescence property was investigated. Emission center wavelength was set to about 420nm. The half-value width (FWHM) of an emission spectrum was set to 32nm. It writes as the configuration which forms a luminous layer 104 in this invention by using p form Lynn-ized boron layer 103 with the low consistency of a misfit rearrangement as a substrate layer. A dark line nonluminescent to a luminescence field (dark line) (Yonezu, the Hiroo work, and "optical-communication component engineering-luminescence and a photo detector" (refer to May 20, Heisei 7, the 5th edition of the Kougaskutosho Co. issue, and 155-156 pages) were not checked by looking, but luminescence of reinforcement with an equal abbreviation was brought about from the whole surface of a luminescence field.) For this reason, the brightness in the chip (chip) condition measured using a common integrating sphere serves as a 8mm candela (mcd), and LED of high luminescence reinforcement will be offered. Moreover, generating of the local poor proof pressure (localbreakdown) based on the effect of a rearrangement was not accepted in the current-electrical-potential-difference (I-V) property of LED1B, but it was shown in it from the configuration of this invention that the light-emitting part 106 of the pn junction mold which presents a good pn junction property (rectifying action) is brought about. LED which the forward voltage (the so-called Vf) for which it asked from the I-V property is 3.6V (forward current = 20mA), and reverse voltage is 6V (reverse current =10microA), and is high pressure-proofing was offered.
[0035]
[Effect of the Invention] A misfit rearrangement is absorbed for the Lynn-ized boron system semi-conductor layer which prepares a front face on Si single crystal substrate made into the {111}-crystal face in this invention. Since it constitutes from a polycrystal layer which gathered the single crystal object containing the twin crystal which can control propagation of a rearrangement The Lynn-ized boron system semi-conductor layer which is excellent in crystallinity with little dislocation density can be constituted, and if this is used, it is effective in the ability to offer the Lynn-ized boron system semi-conductor light emitting device which is excellent in the Lynn-ized boron system semiconductor device which is excellent in a property, for example, luminescence reinforcement, a rectifying action, and pressure resistance.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the mimetic diagram showing the configuration of the single crystal object which constitutes the polycrystal layer concerning this invention.
[Drawing 2] It is the mimetic diagram showing the configuration of the polycrystal layer concerning this invention.
[Drawing 3] It is a mimetic diagram showing the crystal face which intersects the {111} crystal faces of the Lynn-ized boron system semi-conductor layer concerning this invention.
[Drawing 4] It is the mimetic diagram of LED concerning the example of this invention.
[Drawing 5] It is the cross section of LED in alignment with broken-line X-X' of drawing 3 .
[Drawing 6] It is the copy Fig. of the electron diffraction pattern of the Lynn-ized boron layer concerning the example of this invention.
[Description of Notations]
1A Laminating structure
1B LED
11 Si Single Crystal Substrate
12 Lynn-ized Boron System Semi-conductor Polycrystal Layer
13 Single Crystal Object
13a The base of a single crystal object
14 Twin Plane
15 Twin Crystal
16 Plane of Composition of Single Crystal Object
17 {111} Crystal Faces of Single Crystal Object
18 {Hkl} Side
19 Diffraction Spot of Lynn-ized Boron Single Crystal Object
20 Diffraction Spot of Si Single Crystal Substrate
21 Diffraction Spot of Twin Crystal
101 Si Single Crystal Substrate
102 Buffer Coat
103 P Form Lynn-ized Boron Layer
103a Single crystal object
104 Luminous Layer
105 N Form Lynn-ized Boron Layer
105a Single crystal object
106 Light-emitting Part
107 N Form Ohmic Electrode
108 P Form Ohmic Electrode

[Translation done.]